

02/17/00

A

jc682 U.S. PTO
02/16/00



UTILITY PATENT APPLICATION TRANSMITTAL

22193

PATENT TRADEMARK OFFICE

Address to:
**Box PATENT APPLICATION
 Assistant Commissioner for Patents
 Washington, DC 20231**

Attorney Docket No.

1759/USW0573PUS

Inventor(s) or Application Identifier: Angus Dougherty, Donald Hohnstein, Charles Cook, and Guy Wells

jc682 U.S. PTO
02/16/00

1. This application entitled CELLULARIZED PACKETIZED VOICE AND DATA is:
- A new application under 37 C.F.R. § 1.53(b).
 - A continuation divisional or continuation-in-part application under 37 C.F.R. § 1.53(b) of prior application Serial No. / filed on , entitled .

Application elements and other attached papers:

- Specification (incl. Claims and Abstract) [Total Pages 32]
- Drawings (informal formal) [Total Sheets 5]
- Oath or Declaration
 - Newly-executed
 - Copy from a prior application (37 C.F.R. § 1.63(d))
- Incorporation By Reference: The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Item 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
- This application is filed by fewer than all the inventors named in the prior application, 37 C.F.R. § 1.53(d)(4).
 - DELETE** the following inventor(s) named in the prior nonprovisional application:

 - The inventor(s) to be deleted are set forth on a separate sheet attached hereto.

CERTIFICATION UNDER 37 C.F.R. § 1.10

I hereby certify that this UTILITY PATENT APPLICATION TRANSMITTAL and the documents referred to as attached therein are being deposited on the below date with the United States Postal Service in an envelope as "Express Mail Post Office to Addressee" addressed to: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

Express

Mail Label No. EL 503 255 051 US
Angelika Phillips
 (Type or print name of person mailing paper)
Date of Deposit: February 16, 2000
Angelika Phillips
 (Signature of person mailing paper)

7. Preliminary Amendment:

- a. A Preliminary Amendment is attached.
- b. Cancel in this application original claims _____ of the prior application before calculating the filing fee.
- c. Please amend the specification by inserting before the first line the sentence:
"This is a
 continuation
 divisional
of copending application(s)
 Serial number ____ / _____ filed on _____. "
- d. A Petition to Suspend Prosecution For The Time Necessary to File An Amendment (New Application Filed Concurrently) is attached.

8. Small entity status:

- a. A small entity statement is attached.
- b. A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. Is no longer desired.

9. Fee Calculation:

FOR	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS
TOTAL CLAIMS (37 C.F.R. § 1.16(c))	55 -20 =	35	X 18.00	630.00
INDEPENDENT CLAIMS (37 C.F.R. § 1.16(b))	10 -3 =	7	X 78.00	546.00
MULTIPLE DEPENDENT CLAIMS (if applicable) (37 C.F.R. § 1.16(d))			260.00	--
			BASIC FEE (37 C.F.R. § 1.16(a))	690.00
		Total of above Calculations =		1,866
Reduction by 50% for filing by small entity (Note 37 C.F.R. §§ 1.9, 1.27, 1.28)				--
	Assignment Recordal Fee	40.00		--
		TOTAL =		1,866

10. A check in the amount of \$_____ is enclosed.

11. The Commissioner is hereby authorized to credit overpayments or charge the following fees (or any deficiency therein) to U S WEST, Inc. Deposit Account No. 21-0456:

- a. Fees required under 37 C.F.R. § 1.16.
- b. Fees required under 37 C.F.R. § 1.17.

12. Maintenance of Copendency of Prior Application

A request for extension of time and the appropriate fee have been filed in the pending **prior** application (or are being filed in the prior application concurrently herewith) to extend the period for response until _____.

13. An Information Disclosure Statement (IDS) is attached, along with the following indicated attachments thereto:

a. Form PTO/SB/08 (_____ sheet(s))

b. Copies of references cited

14. Certified copy of priority document(s)

15. Return Receipt Postcard

16. Other: _____

17. An Assignment of the invention to _____

a. is attached.

b. was recorded on _____ at Reel _____, Frame _____.

18. The power of attorney in the prior application is to:

Name of Attorney of Record

Reg. No.

The power appears in the original papers in the prior application.

The power does not appear in the original papers, but was filed on _____.

A new power has been executed and is attached.

19. Correspondence Address: Please address all future communications to:

Peter J. Kinsella,

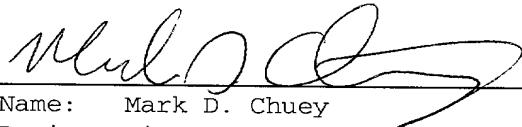


22193

PATENT TRADEMARK OFFICE

Telephone: 877-879-4747 or 303-672-2700; Fax: 303-308-9456

Respectfully submitted,


Name: Mark D. Chuey
Registration No.: 42,415

Date February 16, 2000

Attorney or agent of record
 Filed under Rule 34(a)

CELLULARIZED PACKETIZED VOICE AND DATA

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/152,730 filed September 8, 1999, titled "Cellularized Packetized Voice and Data," the specification of which is expressly incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to wireless communication systems handling a plurality of information types.

10

BACKGROUND ART

15

Communication systems are increasingly being required to provide a wide range of services, including different forms of information communicated and different communication characteristics. Information forms include voice, data, video, telemetry, and the like. Communication characteristics include quality, latency, reliability, cost, availability, portability, and the like. Infrastructure such as telecommunication systems, the Internet, and cable systems exist to provide long-haul routing and information content sourcing. However, difficulty remains in delivering this information to customers. This is particularly the case if the customer is located in a rural location, is communicating through portable equipment, or is mobile.

20

Traditionally, communication service providers have relied on copper wire or coaxial cable to connect distribution sites and subscriber premises. However, increases in the number of users, number and type of communication devices per user, and the information rate per device has strained the ability for traditional communication systems to provide the necessary bandwidth and

25

flexibility. Various technologies including digital subscriber line (DSL) and video modems offer broadband access to the subscriber over existing copper or coaxial loop technologies. Fiber-to-the-home offers broadband access through additional wireline connections. While each technology has broadband delivery properties,
5 each is subject to physical and signaling limitations that restrict availability in certain locations and for certain applications. For example, VDSL is limited to within approximately one kilometer of a connecting central office. Further, each central office usually cannot support high-speed access for every customer within the central office coverage area. Similarly, service provided by two-way cable modems is
10 limited to the installation of coax, hybrid fiber coax and fiber-based systems by the cable provider. This currently results in many premises not having access to high-speed wireline voice, data, and video services.

Wireless systems, such as PCS and cellular systems, offer an alternative to wireline services. Typically, wireless systems include a centralized
15 mobile switching center (MSC) responsible for routing calls, tracking user locations, billing information, and connectivity with other communication systems. The MSC is connected to base station controllers (BSCs), each of which supports one or more base transceiver stations (BTSs). Each BTS supports one or more cells based on the number and configuration of antennas supported by the BTS. Customers
20 communicate with the wireless system through radio telephones when the telephone is within the coverage range of a cell. When a call is placed, a circuit-switched connection is established from the telephone, through the BTS and BSC, to the MSC. The MSC determines the destination and, if the destination is to another telephone within the wireless system, establishes a circuit-switched connection to the
25 destination telephone. If the destination is outside of the wireless system, the MSC routes the call to a service provider for the outside destination.

Cellular and PCS wireless systems have traditionally focused on voice. However, recent introduction of digital radio in both the 800 MHz and 1.9 GHz permits low-speed data services, such as text messaging and one-way paging,
30 to be implemented. Also, wireless modems implementing wireless application protocols may be incorporated into hand-held devices such as lap top personal

computers and personal digital assistants (PDAs). Such devices may offer access to the Internet at rates up to 19.2 kilobits per second.

Several problems have developed with traditional wireless systems. First, because all calls are processed by the central MSC, it can become a bottleneck limiting the number of users supported. Second, if the MSC fails, the system becomes inoperative. Third, the BSC and BTS architecture is fairly rigid, requiring manual reconfiguration in the MSC when components are added or deleted. Fourth, circuit-switched channel connections establish an upper bandwidth, limiting communication rates. Fifth, bandwidth is wasted if the communication rate does not reach the maximum established by the communication channel. Sixth, high-speed data and video applications are impractical on wireless telecommunication systems designed primarily for voice.

An alternative wireless communication system is the local multipoint distribution system (LMDS). In LMDS, an antenna broadcasts high-bandwidth content to local receiving antennas. In the case of Internet access, the return path is typically through slow telephone lines. LMDS, like wireline cable systems, is asymmetrical, making it best suited for distribution of one-way entertainment signals such as television. LMDS also typically operates at a high carrier frequency, requiring receiving antennas to be positioned in line-of-site with the transmitting antenna.

What is needed is a communication system that provides voice, data, and video signals at rates appropriate for each user. The system should make efficient use of bandwidth, allocating only the bandwidth necessary for a particular communication. The system should be flexible, permitting automatic addition and deletion of network components. The system should have distributed routing and service provisioning to prevent bottlenecks, permit scaling, and increase reliability and robustness. The system should be wireless, accommodating a wide variety of fixed, portable, and mobile user communication devices. The system should support high-speed symmetric communication for applications such as video conferencing, real-time distributed document sharing, and the like.

DISCLOSURE OF INVENTION

It is an object of the present invention to provide cellularized wireless packetized access up to and including broadband rates.

5 It is another object of the present invention to provide cellularized packetized voice and data services in a wireless communication system.

It is still another object of the present invention to provide distributed routing of information packets in a wireless communication system.

10 It is yet another object of the present invention to provide the distribution and delivery of wireless voice and data services ubiquitously within the wireless coverage range.

It is a further object of the present invention to provide autonomous bandwidth allocation in a wireless communication system.

15 It is a still further object of the present invention to provide dynamic routing and connectionless packetized voice, data, and video services in a wireless communication system.

It is yet a still further object of the present invention to provide a communication system in which subscriber units can self-provision bandwidth allocation and service access coverage on a per transaction basis.

20 It is yet an additional object of the present invention to provide wireless packetized voice and data radios access to telecommunication and Internet systems.

It is yet another additional object of the present invention to provide a tiered wireless communication system that automatically adapts to the addition or deletion of network components.

In carrying out the above objects and other objects and features of the present invention, a communication system is provided. The communication system includes subscriber units sending and receiving information packets using wireless communication links. The system also includes access points. Each access point 5 forms a coverage area for exchanging information packets with subscriber units within the coverage area. The system further includes distribution points. Each access point communicates with a distribution point. Each distribution point communicates with at least one additional distribution point. Each distribution point receives information packets with a specified destination. If the information packet 10 destination is to a subscriber unit within the coverage area of an access point in communication with the distribution point, the information packet is forwarded to the access point. Otherwise, the information packet is forwarded to one of the additional distribution points. Packets may contain one or more of voice, data, video, streaming audio, streaming video, and the like. Communication links may 15 be symmetrical or asymmetrical.

In various embodiments of the present invention, access points may be in wireline or wireless connection with a distribution point. Also, distribution points may be interconnected by wireline or wireless means. Further, access points may be packaged with a distribution point or may be remotely located from the 20 distribution point.

In another embodiment of the present invention, the communication system includes a communication system interface device capable of formatting information contained in the information packet to pass through a second communication system. A distribution point which receives an information packet 25 for distribution within the second communication system sends the information packet to the second communication system interface device. The second communication system may include a wireless or wireline telecommunication system, a data network such as the Internet, or a video distribution system.

In a further embodiment of the present invention, the distribution point may include one or more of an asynchronous transfer mode switch, an Internet protocol router, an Ethernet router, or a time division multiplexed switch.

5 In yet other embodiments of the present invention, a quality error bit rate is established for each subscriber unit based on one or more of the location of the subscriber unit within the communication system, the class of service, the grade of service, and the rate of service.

10 In yet a further embodiment of the present invention, bandwidth is dynamically allocated when an information packet is exchanged between one of the plurality of subscriber units and one of the plurality of access points.

15 A method for routing packets in a packetized communication system is also provided. Information is broken into a plurality of packets at a transmitting subscriber unit. The plurality of packets are transmitted to a distribution point in communication with the transmitting subscriber unit. Each packet is provided with an address identifying a destination distribution point within the communication system. In each distribution point along a path of distribution points to the destination distribution point, a determination is made as to which distribution point each packet will be forwarded based on the address. If the destination is a subscriber unit in communication with the destination distribution point, when each packet is 20 received at the destination distribution point it is forwarded to the destination subscriber unit where the information is assembled from the plurality of packets.

25 In an embodiment, the method further includes determining that the destination is to a receiver outside of the communication network. Each packet is provided with an address specifying a destination distribution point functioning as a gateway to a communication system supporting the receiver. Each packet is forwarded from the gateway distribution point to the communication system supporting the receiver.

A distribution point for use in a communication system comprising a plurality of networked distribution points is also provided. The distribution point includes at least one front end communication interface for communicating with an access point, the access point in wireless communication with subscriber units currently assigned to the distribution point. The distribution point also includes at least one back end communication interface in communication with a back haul communication device. At least one back haul communication device sends packets to and receives packets from a back haul communication device in another of the networked distribution points. The distribution point further includes an intelligent packet switching device that determines a destination for each received packet and determines if the destination is to a subscriber unit currently assigned to the distribution point. If so, the packet is sent to the destination subscriber unit. If the destination is not to a subscriber unit currently assigned to the distribution point, the switching device determines if the destination is to a subscriber unit currently assigned to any other distribution point in the communication system. If so, another distribution point in back haul communication with the distribution point to which the packet should be forwarded is identified and the packet is forwarded to the identified distribution point.

The above objects and other objects, features, and advantages of the present invention are readily apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIGURE 1 is a schematic drawing illustrating a portion of a communication system according to an embodiment of the present invention;

FIGURE 2 is a block diagram of a distribution point according to an embodiment of the present invention;

FIGURE 3 is a schematic drawing illustrating an implementation of a communication system according to an embodiment of the present invention;

FIGURE 4 is a schematic drawing illustrating an initial state for a communication system according to an embodiment of the present invention;

5 FIGURE 5 is a schematic drawing illustrating the addition of a second access point to the communication system of Figure 4 according to an embodiment of the present invention; and

FIGURE 6 is a schematic drawing illustrating a hierarchical routing system using ATM/IP switches according to an embodiment of the present invention.

10 **BEST MODE FOR CARRYING OUT THE INVENTION**

Referring to Figure 1, a schematic drawing illustrating a portion of a communication system according to an embodiment of the present invention is shown. A communication system, shown generally by 20, includes a plurality of access points 22 which may be, for example, a local radio access point (LRAP).
15 Each access point 22 defines coverage area 24 such as, for example, a cell, covering a reception range of access point 22. Coverage area 24 may be formed from many independent sectors, as may result if access point 22 uses many unidirectional antennas, or may be a single region resulting from the use of an omnidirectional antenna. Subscriber unit 26 within coverage area 24 may establish two-way wireless link 28 with access point 22. Wireless link 28 may be symmetrical or asymmetrical.
20 Subscriber unit 26 may be fixed or non-fixed and, if non-fixed, may possess varying degrees of portability and mobility.

Wireless link 28 may be any form of electromagnetic signaling not confined to a wire or cable, including energy radiated by antenna as well as visible
25 and invisible light. As will be appreciated by one of ordinary skill in the art, wireless link 28 may be implemented by any access technology, including CDMA, TDMA, FDMA, OFDM, analog, and the like. Modulation techniques that may be

used with the present invention include FSK, BPSK, QPSK, m-ary QAM, FM, AM, and the like. Further, the invention does not depend on modulation frequency. In a preferred embodiment, the access technology, frequency, and modulation method for establishing wireless link 28 are based, in part, on local geography, local regulations, noise and distortion sources, other operating wireless systems, cost, and the like. Subscriber unit 26 and access point 22 may establish wireless link 28 using a plurality of combinations of access technology, frequency, and modulation techniques.

Information transmitted in wireless link 28 may represent voice, data, video, streaming audio, streaming video, or the like. Types of information include speech, facsimile, computer data, entertainment and informational audio and video, video games, telemetry, security, and the like. If the information occurs as a continuous stream, subscriber unit 26 breaks the information into packets prior to packet transmission and reassembles the information stream from packets after packet reception. Any type of information that exists in packets or that may be packetized can be used with the present invention.

In an embodiment of the present invention, subscriber unit 26 may be implemented as part of terminal network controller 30 accepting inputs from and providing outputs to information sources including voice equipment 32, computing equipment 34, telemetry equipment 36, video equipment 38, and the like. Inputs to terminal network controller 30 may include serial data, parallel data, ISDN, standard telephone, xDSL, SR 1394, and the like.

In an embodiment of the present invention, a quality error bit rate is established for each subscriber unit 26. This quality error bit rate may be based on the location of subscriber unit 26 within communication system 20, the class of service assigned to subscriber unit 26, the grade of service assigned to subscriber unit 26, the data or transmission rate of service assigned to subscriber unit 26, and the like. The quality error bit rate may be modified while subscriber unit 26 is within communication system 20 to reflect changing conditions such as noise, demand, connectivity, and the like. Applications providing services to subscriber

unit 26 may adjust these services based on the quality error bit rate. For example, an application providing streaming audio and video may reduce the frame update rate as noise increases, guaranteeing successful transmission at a lower information rate. The information rate may be further reduced to provide only still pictures and audio 5 if conditions continue to worsen. The information rate may also be automatically changed if subscriber unit 26 moves between coverage areas 24 with differing transmission capabilities or loads.

Control of the information rate may be achieved by having subscriber unit 26 monitor a signaling channel transmitted by access point 22 for each coverage 10 area 24. This signaling channel informs subscriber unit 26 when to transmit information, how much information to transmit, the information transmission rate, and the like. The signaling channel may be controlled by a central supervisor, described below.

In an embodiment of the present invention, bandwidth on communication link 28 is only consumed when packets containing information are transmitted. For example, each subscriber unit 26 surrenders bandwidth on communication link 28 when not sending or receiving an information packet. Packets to be transmitted are queued based on order of arrival, priority, a combination of arrival order and priority, or the like. Subscriber unit 26 monitors 15 a signaling channel transmitted by access point 22 for each coverage area 24. Subscriber unit 26 only consumes bandwidth when instructed to transmit by the signaling channel or when receiving packets.

Each access point 22 communicates with at least one distribution point 40. Distribution point 40 contains both routing and switching functionality. Access 25 point 22 may be in contact with one or more radio access distribution points 40 over radio link 42, may be wired or cabled to distribution point 40 through wireline link 44, or may be packaged with distribution point 40. Access point 22 may also be transformed into distribution point 40, permitting access point 22 to route traffic that neither originated nor terminated with any of its serviced subscriber units 26. 30 Distribution point 40 is in communication with at least one additional distribution

point 40, the collection of interconnected distribution points forming a network of distribution points, shown generally by 41. Two distribution points may be connected by radio link 46 or wireline link 48.

Distribution points 40 may route packets within distribution point network 41 under a variety of protocols such as ATM, TCP/IP, 802.x, or the like. In a preferred embodiment, distribution point 40 includes an ATM/IP switch. Distribution point 40 then operates at both the IP routing and ATM switching layers or, in terms of the Open Systems Interconnection (OSI) standard, at both the network layer and the data link layer.

The IP layer operates with a link-state protocol such as the open shortest path first (OSPF), quality OSPF (Q-OSPF), or internal gateway routing protocol (IGRP) and its derivatives. The IP layer operates as a single autonomous system (AS) within the IP frame of reference. Each system 20 will be allocated a unique and unambiguous AS number for system management. IP addresses for system 20 will use a private IP address space that cannot be routed within public systems such as the Internet. Subscriber units 26 within system 20 may be permitted access to the private IP address space or may be excluded from the private IP address space. When private IP address space is used for subscriber units 26, a network address translator (NAT) within system 20 allows subscriber units 26 access to the Internet. The ATM layer operates with the private network node interface (PNNI) routing protocol. ATM end system addresses (AESAs), managed by the service provider for system 20, are used by distribution point network 41.

The ATM network carries voice traffic. Through PNNI, the ATM/IP switch participates in switched or signaled virtual connections (SVCs). When subscriber unit 26 within system 20 requires voice connectivity, it signals such a request, which is serviced by distribution point 40 receiving that request. The IP network coresiding with the ATM network is used for data applications required by subscriber units 26. The IP network is also used for all network management, including management of ATM/IP switches, subscriber units 26, gear associated with distribution points 40, and the like. This includes functions such as alarming,

monitoring, recovery systems, and the like. While described in the context of a wireless network application, it is readily apparent that ATM/IP routing as described herein may be applied to wireline and mixed wireline-wireless systems as well.

Each distribution point 40 receives an information packet from either
5 another distribution point 40, from subscriber unit 26 in communication with
distribution point 40 through access point 22, or from an external communication
system. If distribution point 40 determines the information packet is destined for
subscriber unit 26 within coverage area 24 of access point 22 in communication with
distribution point 40, distribution point 40 forwards the packet to access point 22
10 forming coverage area 24 containing destination subscriber unit 26. If distribution
point 40 determines the information packet is destined for subscriber unit 26 in
coverage area 24 formed by access point 22 in communication with a different
distribution point 40, distribution point 40 forwards the packet to one of distribution
points 40 in communication with distribution point 40. Hence, no central MSC is
15 required for routing. Distributed routing removes delays caused by central
switching, increases the robustness of the communication system 20, and permits
simplified expansion or reduction of communication system 20 by automatically
adding or removing distribution points 40.

A third option is that distribution point 40 determines that the
20 information packet is destined for a destination not part of communication system 20.
Special distribution points, such as gateway 50, provide a bridge to additional
communication systems 52 including wireless and wireline telecommunication
systems, video distribution systems, computer network systems such as the Internet,
packet systems, frame systems, ATM systems, IP systems, private networks, and the
25 like. If distribution point 40 determines the information packet is destined for
delivery outside of communication system 20, distribution point 40 forwards the
packet to one of distribution points 40 in communication with gateway 50.

In an embodiment of the present invention, communication system 20
includes communication system interface device 54 operative to format information
30 contained in the information packet to pass through telecommunication system 52.

Communication system interface device 54 may be incorporated into gateway 50 or may be a separate component of communication system 20. Distribution point 40 receives at least one information packet from the telecommunication system interface device 54 and determines if the at least one information packet destination is to subscriber unit 26 within coverage area 24 of access point 22 in communication with distribution point 40. Distribution point 40 forwards the at least one information packet to access point 22 defining coverage area 24 containing subscriber unit 26 if the information packet destination is to subscriber unit 26 within coverage area 24 of access point 22 in communication with distribution point 40 and forwards the at least one information packet to one of the additional distribution points 40 in communication with distribution point 40 otherwise.

Each distribution point 40 communicates with supervisor 56. Supervisor 56 tracks the locations of subscriber units 26 within communication system 20, identifying with which distribution point 40 each subscriber unit 26 is currently communicating. Supervisor 56 manages transmission priorities based on parameters including load, information type, service requests, location, grade of service, information transfer rates, and the like. In an embodiment of the present invention, supervisor 56 also assigns an address to each distribution point 40 as distribution point 40 is added to communication system 20. Supervisor 56 provides each distribution point 40 with a logical address and a listing indicating to which additional distribution point 40 in communication with distribution point 40 information packets should be forwarded for each possible destination distribution point 40. The listing may be based on maintaining a minimum quality of service in the path through distribution point network 41 to the destination distribution point 40. Supervisor 56 periodically assesses the performance of network 41 by sending test messages. Reports may also be generated by distribution points 40 attempting to communicate with target addresses.

Supervisor 56 is shown in Figure 1 as a separate component individually connected to each distribution point 40. Alternatively, communication between supervisor 56 and distribution points 40 may be through radio links 46 and wireline links 48. Supervisor 56 may be one or more separate components of

communication system 20, may be incorporated into one of distribution points 40, or may be distributed amongst multiple distribution points 40.

In an embodiment of the present invention, a distribution point may be automatically added to or removed from distribution point network 41. When 5 new distribution point 40 is first inserted into communication system 20, new distribution point 40 transmits a signature signal. Existing distribution points 40 within range of new distribution point 40 receive the signal and report it to supervisor 56. Supervisor 56 then determines if new distribution point 40 will be added to network 41. If so, supervisor 56 assigns new distribution point 40 a 10 routing address and informs network 41 as needed. Each existing distribution point 40 in distribution point network 41 is provided with an indication as to which distribution point 40 in communication with existing distribution point 40 each information packet having a destination address specifying the new distribution point 40 is to be forwarded. If a distribution point 40 is removed from network 41, 15 remaining distribution points 41 report the absence of removed distribution point 40 to supervisor 56. Supervisor 56 then informs network 41 as needed.

In an embodiment of the present invention, each subscriber unit 26 is autonomously registered with communication system 20 when subscriber unit 26 first enters coverage area 24 within communication system 20. Each subscriber unit 20 26 maintains registration as subscriber unit 26 moves from one coverage area 24 into another coverage area 24 within communication system 20 and is autonomously deregistered when subscriber unit 26 leaves communication system 20. To accomplish automatic registration and deregistration of subscriber units 26, each access point 22 periodically reports the status of subscriber units 26 within any 25 controlled coverage area 24 to supervisor 56 performing registration and authentication. Each access point 22 communicates with subscriber units 26 to determine status. When a subscriber unit 26 voluntarily enters or leaves coverage area 24, such as by powering up or down, subscriber unit 26 transmits a particular signal to access point 22. Information is also received from subscriber unit 26 in 30 response to periodic queries from network 20. Access point 22 may determine the absence of subscriber unit 26 from coverage area 24 if no communication is received

after a particular time interval. Algorithms for registering and deregistering subscriber units 26 may be based on various factors including quality of service, traffic, location, service type, network topology, and the like.

Referring now to Figure 2, a block diagram of a distribution point according to an embodiment of the present invention is shown. Distribution point 40 includes one or more front end communication interfaces 100, each front end interface communicating with one access point 22. In one configuration, access point 22 is packaged with distribution point 40. Front end interface 100 may provide a plug-in port for receiving access point 22. In another configuration, front end interface 100 connects to antenna 102 for establishing radio link 42 with access point 22. In a further configuration, front end interface 100 accepts wireline link 44 connecting distribution point 40 with access point 22. Front end interface 100 operates using a standard packet switching protocol such as, for example, ATM25. Each front end communication interface 100 passes information packets through common front end switch interface 104 operating under a packet protocol such as ATM, TCP/IP, 802.x, or the like.

Distribution point 40 also includes back end communication interfaces 106 for connecting distribution point 40 with additional distribution points 40, with supervisor 56, and, if distribution point 40 is a gateway 50, with telecommunication systems, private network systems, video distribution systems, the Internet, or the like. This may be typically referred to as back haul communication. In one configuration of the present invention, back end interface 106 connects to antenna 108 for establishing radio link 46 with another distribution point 40. In another configuration, back end interface 104 accepts wireline link 44 connecting distribution point 40 with another distribution point 40. In a preferred embodiment, back end interface 106 accepts modules 110 for interfacing through a variety of protocols and media such as ATM25, DS1, DS3, OC3, 1000Base-T, 100Base-T, and the like. Each back end communication interface 106 passes information packets through common back end switch interface 112 operating under a packet protocol such as ATM, TCP/IP, or the like. In a preferred embodiment, distribution point 40

dynamically allocates bandwidth when the information packet is forwarded to one of the additional distribution points 40 in communication with distribution point 40.

Intelligent packet switch 114 received information packets through common front end switch interface 104 and common back end switch interface 112 and routes the packets between front end interfaces 100 and back end communication interfaces 106. Switch 114 may be a packet switching device as is known in the art such as an ATM switch, an IP switch, a TDM switch, a switch working under the 802.11 specification, or any other suitable alternative or combination having the required switching functionality. In an embodiment of the present invention, switch 114 includes an ATM portion for voice and video routing and an IP portion for data routing as well as administration, management, and network topology control.

In an embodiment of the present invention, distribution point 40 is enclosed in an environmentally sealed package. This permits distribution point 40 to be mounted outside, such as on a pole or the side of a building. In keeping with the invention, however, distribution point 40 need not be outside so long as it can communicate with access points 22, additional distribution points 40, supervisor 56, and the like.

Referring now to Figure 3, a schematic drawing illustrating an implementation of a communication system according to an embodiment of the present invention is shown. This implementation provides an example including interfaces between communication system 20 and a variety of external communication systems 52.

Communication system 20 includes wireless service location registers (WSLRs) 200 providing common subscriber and service databases. Each WSLR 200 communicates with at least one distribution point 40 and one additional communication system 52. Connections between WSLRs 200 and communication systems 52 are not shown in Figure 3 for clarity. Each WSLR 200 provisions requested services from additional communication system 52. For example, WSLR 200 may provide centralized mobility and location management. Supervisor 56

determines which WSLR 200 will provision services based on the distribution point 40 through which subscriber unit 26 requesting services is currently communicating. A device that may serve as WSLR 200 is described in U.S. Patent No. 5,974,331 titled "Method And System For Dynamically Assigning Features And Users To 5 Wireline Interfaces," to Cook *et al.*, which is herein incorporated by reference.

Communication system 20 may also include multi-service platform (MSP) 202. MSP 202 provides access to wireline telephone systems (PSTN). This may be accomplished through GR-303 compliant connection 204. Signaling point of interface (SPOI) 206 serves as the demarcation point between communication 10 system 20 and external communication system 52. In the example shown, GR-303 connection 204 connects wireline provider 208, serving wired customers 210, with communication system 20. MSP 202 may integrate both PSTN and IP networks as well as provide enhanced circuit/packet switch services.

At least one gateway 212 supports MSP 202. Communication system 15 20 may include, for example, voice-over-ATM (VoATM) to GR-303 gateways and voice over IP (VoIP) to GR-303 gateways. Gateway 212 serves as a call agent, converting information packets to a format acceptable to additional communication system 52. A determination as to which gateway 212 will process an information packet may be based on information contained within the information packet. 20 Gateways 212 may be connected to MSP 202 by GR-303 compliant connection 214.

Communication system 20 may also include gateway 216 connecting communication system 20 with external data network 52 such as the Internet or a private data network interconnecting network users 218. Gateway 216 may, for example, convert between various packet-based standards such as H.323 and SIP.

Communication system 20 may also include gateway 220 interfacing 25 communication system 20 with external SS7 network 52 represented by signal transfer point (STP) 222. Gateway 220 communicates with STP 222 through ISUP compliant connection 224 which permits setting up and taking down trunk calls, calling party information services, call status, and the like, by passing signaling

information through SS7 network 52 to wireline provider 208 under the control of integrated services control point (ISCP) 226.

Communication system 20 may also include unified message center (UMC) 228. Unified messages, also known as integrated messages, permit messages from a variety of sources such as telephone, email, fax, reports, compound documents, and the like, to be summarized and presented on a single medium, such as a personal computer. Messages may even be translated from one media type to another. UMC 228 supports unified message applications within communication system 20. In an embodiment, UMC 228 communicates with wireline provider 208, permitting greater integration, flexibility and access to messages.

Connection controller 230 controls access to gateways 50, 202, 212, 216, 220, and the like. For example, connection controller 230 may manage voice over ATM to GR-303 access, voice over IP to GR-303 access, H.323/SIP to Internet remote access, SS7 to IP access, and the like. Connection controller 230 may also support information rate adaptation including open application processor interfaces and robust application development platforms.

Referring now to Figures 4-6, drawings illustrating dynamic growth of a distribution point network according to an embodiment of the present invention are shown. An initial configuration for system 20 is shown in Figure 4. ATM/IP switch 300 is in communication with supervisor 56 through ATM virtual connection 302. In this simple configuration, ATM/IP switch 300 may be functioning as access point 22. ATM/IP switch 300 may obtain an IP address and an ATM address either manually or automatically.

ATM/IP switch 300 automatically requests addresses by first broadcasting an ATM request in an IP packet over virtual connection (VC) 302. Supervisor 56 forwards this request to address server 304. Address server 304 responds by allocating unique AESA 306 to the address assignment client in ATM/IP switch 300, which updates the ATM layer with new address 306. The address assignment client in ATM/IP switch 300 next requests from address server 304 an

IP address, again using IP as the transport service over pre-existing ATM VC 302. Address server 304 forwards IP address 308 to ATM/IP switch 300. ATM/IP switch 300 then requests address pools for ATM and IP. Address server 304 responds by supplying AESA pool 310 and IP address pool 312. Pools of addresses 5 310, 312 are used by switch 300 when functioning as distribution point 40 in support of other distribution points 40 and access points 22.

Referring now to Figure 5, a drawing illustrating the addition of a second access point is shown. Access point 22 has the capability to function as a distribution point 40. As new access points 22 are subtended from an existing access 10 access point 22, existing access point 22 becomes a distribution point 40. Each distribution point 40 continues to communicate with its initially connected distribution point 40 and with other distribution points 40 as they are provisioned. As new links 46, 48 between distribution points are created, distribution points 40 form peer relationships at both the ATM layer and the IP layer. Distribution points 40 are always peers at 15 the IP and ATM layer, while access points 22 are clients of distribution points 40. As such, each ATM/IP switch 300 functions as a server when operating as distribution point 40 and as a client when operating as access point 22.

When new ATM/IP switch 320 is instantiated as access point 22, it will automatically request an ATM address in an IP packet address assignment 20 request. This IP packet will be sent in an ATM frame over radio link 46 to IP/ATM switch 300 functioning as distribution point 40 using a pre-existing ATM VC. IP/ATM switch 300 will allocate unique ATM address 322 from AESA pool 310 and unique IP address 324 from IP address pool 312. ATM/IP switch 320 then sends a directed request to address server 304 and receives its own AESA pool 326 and IP 25 address pool 328.

Referring now to Figure 6, a hierarchical routing network is shown. Address server 304 assigns AESA pool 310 and IP address pool 312 as each ATM/IP switch 300 is added. By handling all requests for address pools 310, 312, address server 304 maintains a hierarchy of addresses for both ATM and IP layers. 30 Address server 304 constructs routing tables for each ATM/IP switch 300 indicating

to which directly connected ATM/IP switch 300 each incoming packet should be routed if the packet is not destined to subscriber unit 26 serviced by that ATM/IP switch 300. Thus, routing tables are cohesive, reflecting the view of communication system 20 seen by each ATM/IP switch 300. Address server 304 also constructs 5 forward equivalency class (FEC) tables permitting ATM/IP switch 300 to route packages based on package contents. FECs can be seen as either the virtual path identifier (VPI) portion of the ATM VPI/VCI or as the entire VPI/VCI, and are enabled by the routing protocols at the IP and PNNI layers.

When subscriber unit 26 first enters communication system 20, it is 10 detected and serviced by access point 22. Subscriber unit 26 is provided with one or more addresses, each address routable within at least the local hierarchy of ATM/IP switches 300. If subscriber unit 26 enters the range of a new access point 22, new access point 22 sends out a flooding FEC routing update for the ATM address of subscriber unit 26. Previously servicing access point 22 removes 15 subscriber unit 26 from its own FEC upon receiving the FEC update. Any subsequent ATM packets received by previously servicing access point 22 are discarded.

When subscriber unit 26 changes access points 22, the IP routing portion of system 20 moves the IP address of subscriber unit 26 from one FEC class 20 to another. Any IP packets remain untouched, with only a label or equivalence changed. In one embodiment, the label is the VPI portion of the VC. In another embodiment, multiprotocol label switching (MPLS) is used to provide an additional label. In either case, the IP address and virtual connection identifier (VCI) are retained.

25 While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

- 1 1. A communication system comprising:
 - 2 a plurality of subscriber units, each subscriber unit sending and
 - 3 receiving information packets using a wireless communication link;
 - 4 a plurality of access points, each access point forming a coverage area
 - 5 for exchanging information packets with subscriber units within the coverage area
 - 6 through at least one wireless communication link; and
 - 7 a plurality of distribution points, each distribution point in
 - 8 communication with at least one access point and with at least one additional
 - 9 distribution point, each distribution point operative to
 - 10 (a) receive an information packet for distribution to a destination
 - 11 within the communication system,
 - 12 (b) determine if the information packet destination is to a
 - 13 subscriber unit within the coverage area of an access point in
 - 14 communication with the distribution point,
 - 15 (c) forward the information packet to the access point defining
 - 16 the coverage area containing the subscriber unit if the
 - 17 information packet destination is to a subscriber unit within
 - 18 the coverage area of the access point in communication with
 - 19 the distribution point, and
 - 20 (d) forward the information packet to one of the additional
 - 21 distribution points in communication with the distribution
 - 22 point if the information packet destination is not to a
 - 23 subscriber unit within the coverage area of the access point in
 - 24 communication with the distribution point.
- 1 2. A communication system as in claim 1 wherein each
- 2 information packet includes at least one of voice, video, and data information.
- 1 3. A communication system as in claim 1 wherein an information
- 2 packet comprises voice information.

1 4. A communication system as in claim 1 wherein an information
2 packet comprises video information.

1 5. A communication system as in claim 1 wherein an information
2 packet comprises data.

1 6. A communication system as in claim 1 wherein an information
2 packet comprises streaming audio.

1 7. A communication system as in claim 1 wherein an information
2 packet comprises streaming video.

1 8. A communication system as in claim 1 wherein the
2 communication link is a symmetric link.

1 9. A communication system as in claim 1 wherein the
2 communication link is an asymmetric link.

1 10. A communication system as in claim 1 wherein the distribution
2 point is in wireless communication with at least one access point.

1 11. A communication system as in claim 1 wherein the distribution
2 point is in wireline communication with at least one access point.

1 12. A communication system as in claim 1 wherein at least one
2 access point is packaged with the distribution point.

1 13. A communication system as in claim 1 wherein at least one
2 access point is not collocated with the distribution point.

1 14. A communication system as in claim 1 wherein at least one
2 distribution point is in wireless communication with at least one additional
3 distribution point.

1 15. A communication system as in claim 1 wherein the plurality
2 of distribution points forms a wireless network of distribution points.

1 16. A communication system as in claim 1 further comprising a
2 communication system interface device operative to format information contained in
3 the information packet to pass through a second communication system, the
4 distribution point further operative to receive an information packet for distribution
5 within the second communication system and to send the information packet to the
6 second communication system interface device.

1 17. A communication system as in claim 16 wherein the second
2 communication system comprises a wireless telecommunication system.

1 18. A communication system as in claim 16 wherein the second
2 communication system comprises a wireline telecommunication system.

1 19. A communication system as in claim 16 wherein the second
2 communication system comprises a data network.

1 20. A communication system as in claim 16 wherein the second
2 communication system comprises a video distribution system.

1 21. A communication system as in claim 1 further comprising a
2 telecommunication system interface device operative to format information contained
3 in the information packet to pass through a telecommunication system, the
4 distribution point further operative to:

5 receive at least one information packet from the telecommunication
6 system interface device;

7 determine if the at least one information packet destination is to a
8 subscriber unit within the coverage area of an access point in communication with
9 the distribution point;

10 forward the at least one information packet to the access point
11 defining the coverage area containing the subscriber unit if the information packet
12 destination is to a subscriber unit within the coverage area of the access point in
13 communication with the distribution point; and

14 forward the at least one information packet to one of the additional
15 distribution points in communication with the distribution point if the information
16 packet destination is not to a subscriber unit within the coverage area of the access
17 point in communication with the distribution point.

1 22. A communication system as in claim 1 wherein the distribution
2 point is further in communication with an Internet gateway, the distribution point
3 further operative to exchange packets with the Internet gateway.

1 23. A communication system as in claim 1 wherein at least one
2 distribution point comprises an asynchronous transfer mode switch.

1 24. A communication system as in claim 1 wherein at least one
2 distribution point comprises an Internet protocol router.

1 25. A communication system as in claim 1 wherein at least one
2 distribution point comprises an Ethernet router.

1 26. A communication system as in claim 1 wherein at least one
2 distribution point comprises a TDM switch.

1 27. A communication system as in claim 1 wherein each subscriber
2 unit is autonomously registered when the subscriber unit first enters the coverage
3 area of a radio access point within the communication system.

1 28. A communication system as in claim 27 wherein each
2 subscriber unit maintains registration as the subscriber unit moves from one coverage
3 area into another coverage area.

1 29. A communication system as in claim 27 wherein each
2 subscriber unit is autonomously deregistered when the subscriber unit leaves the
3 communication system.

1 30. A communication system as in claim 1 wherein a quality error
2 bit rate is established for each subscriber unit based on the location of the subscriber
3 unit within the communication system.

1 31. A communication system as in claim 1 wherein a quality error
2 bit rate is established for each subscriber unit based on the class of service.

1 32. A communication system as in claim 1 wherein a quality error
2 bit rate is established for each subscriber unit based on the grade of service.

1 33. A communication system as in claim 1 wherein a quality error
2 bit rate is established for each subscriber unit based on the rate of service.

1 34. A communication system as in claim 1 wherein the subscriber
2 unit is a fixed device.

1 35. A communication system as in claim 1 wherein the subscriber
2 unit is a non-fixed device.

1 36. A communication system as in claim 1 wherein the distribution
2 point dynamically allocates bandwidth when the information packet is forwarded to
3 one of the additional distribution points in communication with the distribution point.

1 37. A communication system as in claim 1 wherein bandwidth is
2 dynamically allocated when an information packet is exchanged between one of the
3 plurality of subscriber units and one of the plurality of access points.

1 38. A method for routing packets in a packetized communication
2 system including a plurality of subscriber units comprising:

3 establishing a distributed network of distribution points;
4 breaking information into a plurality of packets at a transmitting
5 subscriber unit, each subscriber unit in communication with at least one distribution
6 point in the network of distribution points;
7 transmitting the plurality of packets to a distribution point in
8 communication with the transmitting subscriber unit;
9 providing each packet of the plurality of packets with an address, the
10 address indicating a destination distribution point within the communication system;
11 in each distribution point along the path of distribution points to the
12 destination distribution point, determining to which distribution point each packet
13 will be forwarded based on the address;
14 receiving each packet in the destination distribution point;
15 forwarding each packet to a destination subscriber unit if the
16 destination is a subscriber unit in communication with the destination distribution
17 point; and
18 assembling the information from the plurality of packets at the
19 destination subscriber unit.

1 39. A method for routing packets as in claim 38 further
2 comprising:
3 determining that the destination is to a receiver outside of the
4 communication network;
5 providing each packet with an address specifying a destination
6 distribution point functioning as a gateway to a communication system supporting
7 the receiver if the destination is determined to be to a receiver outside of the
8 communication network; and
9 forwarding each packet from the gateway distribution point to the
10 communication system supporting the receiver.

1 40. A communication system comprising a plurality of subscriber
2 units, each subscriber unit in communication with at least one distribution point in
3 a network of distribution points, each subscriber unit sending and receiving
4 information as a plurality of packets over a communication link, each subscriber unit

5 operative to surrender communication link bandwidth when not sending or receiving
6 an information packet.

1 41. A communication system comprising a plurality of subscriber
2 units, each subscriber unit in communication with at least one distribution point in
3 a network of distribution points, each subscriber unit sending and receiving
4 information as a plurality of packets transmitted over a communication link, wherein
5 communication link bandwidth is only consumed when packets containing
6 information are transmitted, thereby only utilizing link bandwidth when information
7 is sent or received.

1 42. A method of utilizing bandwidth in a packetized
2 communication link shared between a plurality of subscriber units comprising:
3 selecting one of the plurality of subscriber units for transmitting;
4 broadcasting an identification of the selected subscriber unit over a
5 signaling channel;
6 determining within the selected subscriber unit any packets are to be
7 transmitted;
8 transmitting the determined packets over an information channel; and
9 queuing packets within nonselected subscriber units for later
10 transmission.

1 43. A communication system comprising:
2 a plurality of distribution points, each distribution point in
3 communication with at least one additional distribution point in the plurality of
4 distribution points, each distribution point operative to rout information packets;
5 a plurality of subscriber units, each subscriber unit operative to
6 communicate information packets to a destination subscriber unit through at least one
7 distribution point in the plurality of distribution points; and
8 a supervisor in communication with each distribution point, the
9 supervisor operative to identify the distribution point with which each subscriber unit
10 is communicating.

1 44. A communication system comprising:
2 a plurality of distribution points, each distribution point in
3 communication with at least one additional distribution point in the plurality of
4 distribution points, each distribution point operative to forward each information
5 packet received by the distribution point to another distribution point based on a
6 destination address in the packet and on a logical address of each of the plurality of
7 distribution points; and

8 a supervisor in communication with each distribution point, the
9 supervisor operative to provide each distribution point with a listing of to which of
10 the at least one additional distribution point in communication with the distribution
11 point information packets should be forwarded for each possible destination
12 distribution point, the listing based on maintaining a minimum quality of service in
13 the path to the destination distribution point.

1 45. A method of automatically adding a distribution point into a
2 network of distribution points, each existing distribution point in the network of
3 distribution points in communication with at least one additional distribution point,
4 each distribution point operative to forward an information packet to one of the
5 additional distribution points in communication with the existing distribution point
6 based on a destination address in the information packet, the method comprising:

7 transmitting a sign-on signal from the new distribution point;
8 receiving the sign-on signal by at least one existing distribution point
9 in the network of distribution points;

10 assigning a routing address to the new distribution point; and
11 providing each existing distribution point with an indication as to
12 which additional distribution point in communication with the existing distribution
13 point each information packet having a destination address specifying the new
14 distribution point is to be forwarded.

1 46. A method of automatically removing a distribution point from
2 a network of distribution points, each distribution point in the network of distribution
3 points in communication with at least one additional distribution point, each
4 distribution point operative to forward an information packet to one of the additional

5 distribution points in communication with the distribution point based on a
6 destination address in the information packet, the method comprising:

7 detecting the absence of signal from a distribution point to be removed
8 from the network;

9 determining a connectivity between distribution points remaining after
10 removing the distribution point detected with the absence of signal; and

11 providing each remaining distribution point with an indication as to
12 which distribution point in communication with the remaining distribution point each
13 information packet having a destination address specifying the new distribution point
14 is to be forwarded.

1 47. A distribution point for use in a communication system
2 comprising a plurality of networked distribution points, the distribution point
3 comprising:

4 at least one front end communication interface, each front end
5 interface in communication with an access point, the access point in wireless
6 communication with subscriber units currently assigned to the distribution point;

7 at least one back end communication interfaces, each back end
8 interface in communication with a back haul communication device, at least one back
9 haul communication device transferring packets with a back haul communication
10 device in another of the plurality of networked distribution points; and

11 an intelligent packet switching device operative to
12 (a) determine a destination for each received packet,
13 (b) determine if the destination is to a subscriber unit currently
14 assigned to the distribution point,
15 (c) send the packet to the destination subscriber unit if the
16 destination subscriber unit is currently assigned to the
17 distribution point,
18 (d) if the destination is not to a subscriber unit currently assigned
19 to the distribution point, determine if the destination is to a
20 subscriber unit currently assigned to any other distribution
21 point in the communication system, and

1 48. A distribution point as in claim 47 wherein at least one front
2 end communication interface is connected to an antenna, thereby permitting the
3 distribution point to be in wireless communication with at least one radio access
4 point.

1 49. A distribution point as in claim 47 wherein at least one front
2 end communication interface is in wireline connection with a radio access point.

1 50. A distribution point as in claim 47 wherein transferring packets
2 between a back haul communication device within the distribution point and a back
3 haul communication device in another of the plurality of networked distribution
4 points is a wireless transfer.

1 51. A distribution point as in claim 47 wherein transferring packets
2 between a back haul communication device within the distribution point and a back
3 haul communication device in another of the plurality of networked distribution
4 points is through a wireline connection.

1 52. A distribution point as in claim 47 wherein the intelligent
2 packet switching device comprises an asynchronous transfer mode switch.

1 53. A distribution point as in claim 47 wherein the intelligent
2 packet switching device comprises an Internet protocol router.

1 54. A distribution point as in claim 47 wherein the intelligent
2 packet switching device comprises an Ethernet router.

1 55. A distribution point as in claim 47 wherein the intelligent
2 packet switching device comprises a TDM switch.

ABSTRACT OF THE DISCLOSURE

Distributed routing provides a robust, scalable communication system free of bottlenecks associated with traditional wireless systems. The system includes subscriber units sending and receiving information packets using wireless communication links. The system also includes access points with each access point forming a coverage area for exchanging information packets with subscriber units within the coverage area. The system further includes distribution points receiving packets from access points. Distribution points form a distributed routing network. Each distribution point receives an information packet for distribution to a specified destination. If the destination is to a subscriber unit within the coverage area of the access point in communication with the distribution point, the information packet is forwarded to the access point. Otherwise, the information packet is forwarded to one of the additional distribution points.

DRAFT - PENDING

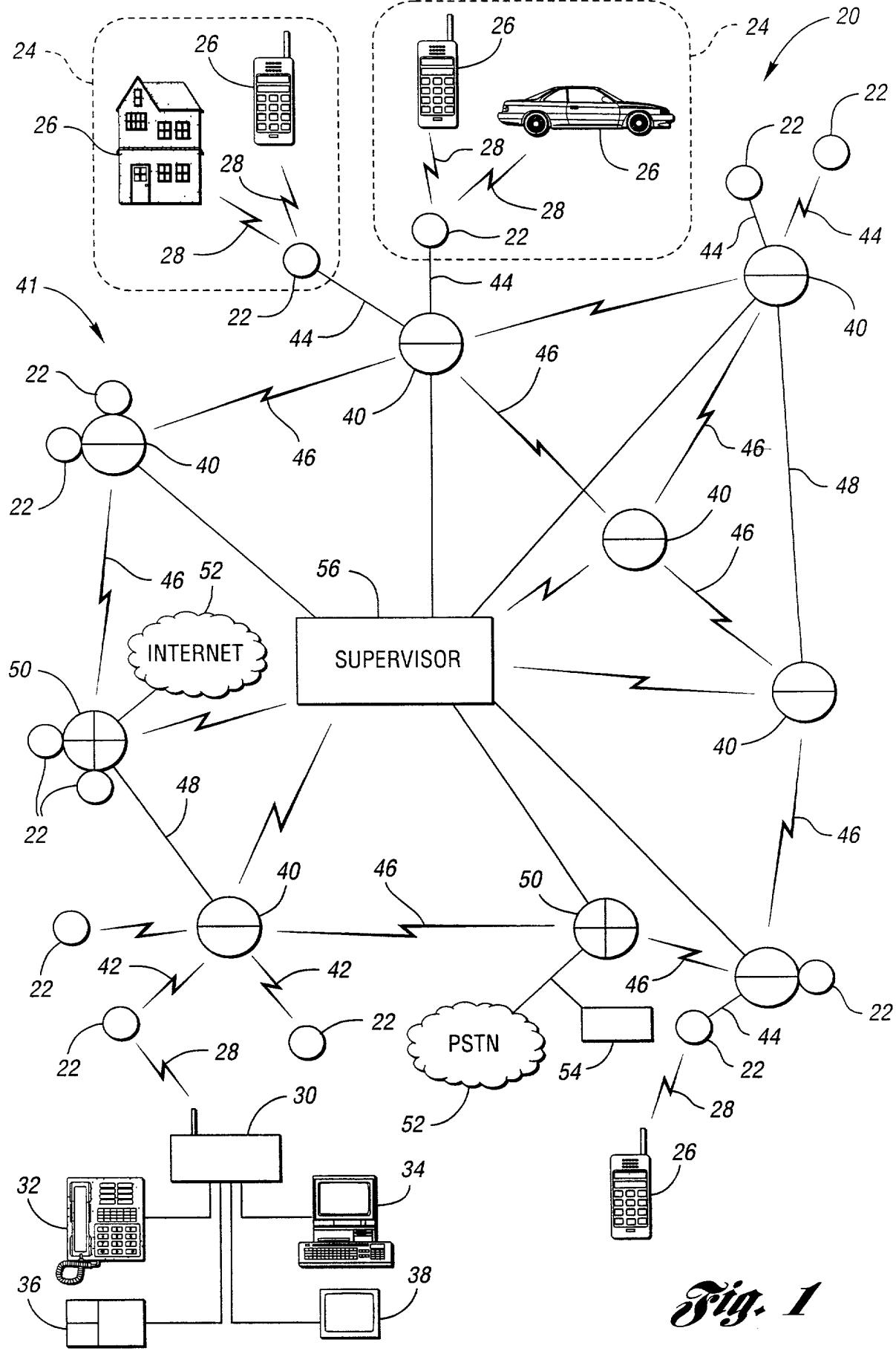


Fig. 1

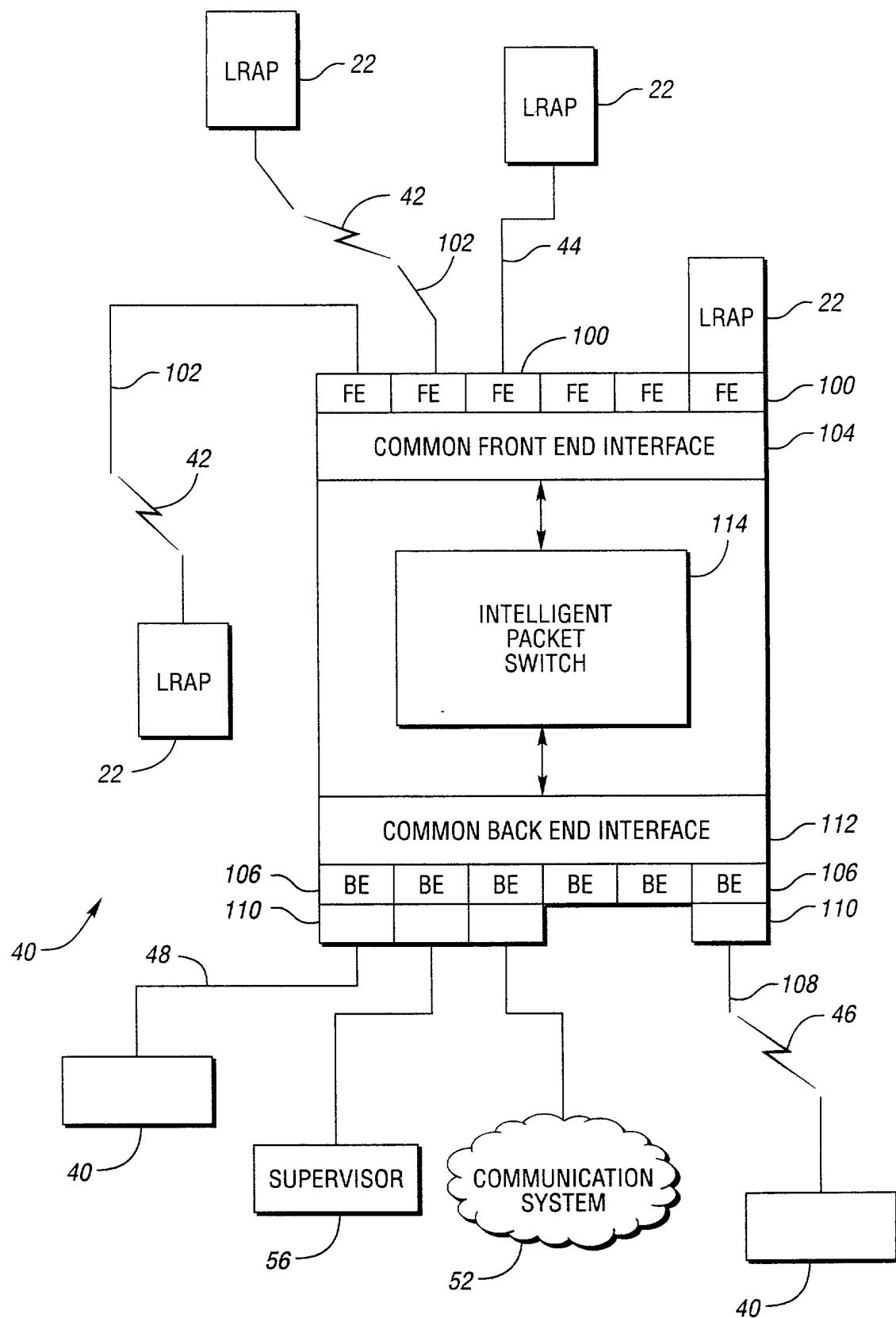
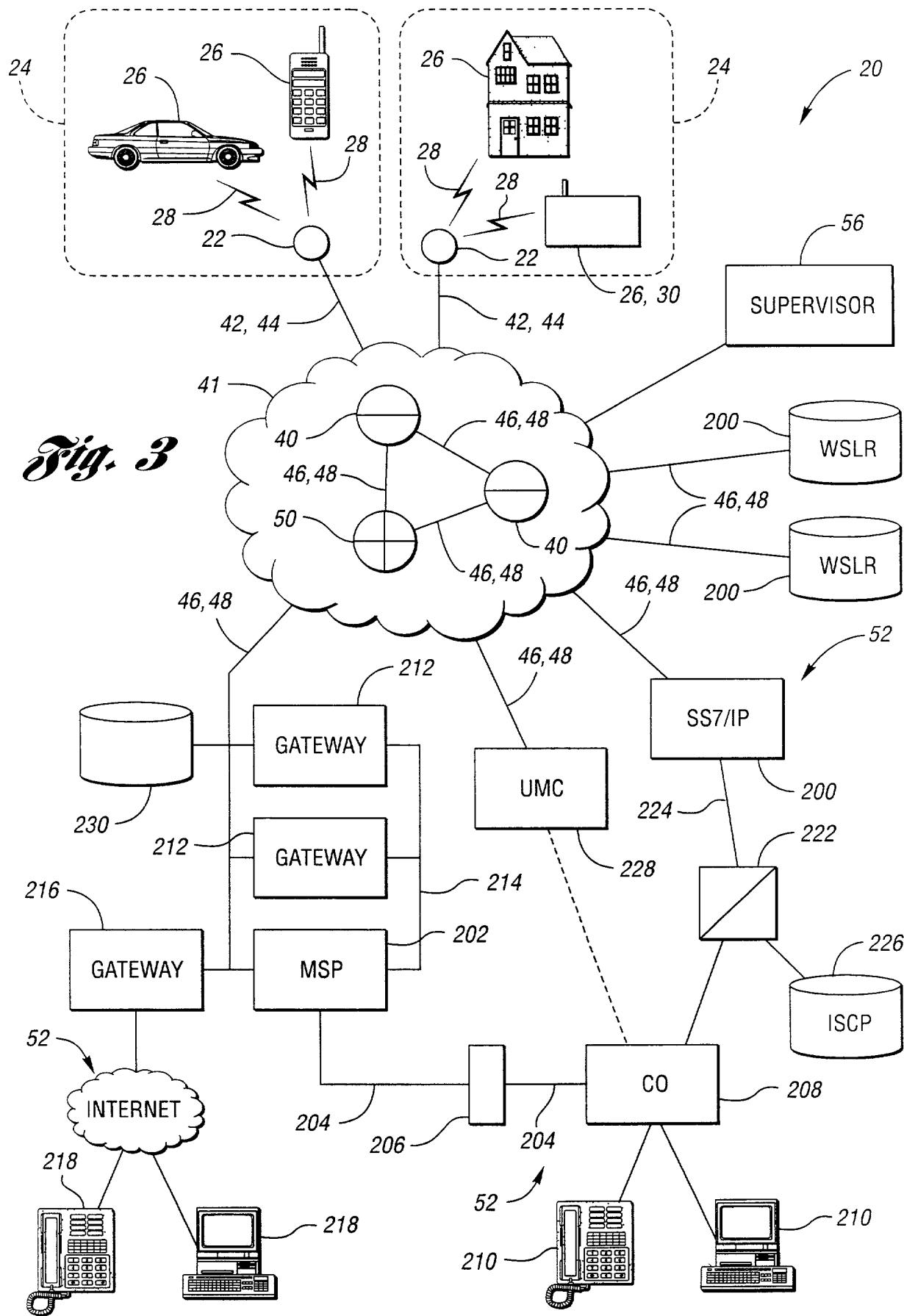


Fig. 2

Fig. 3



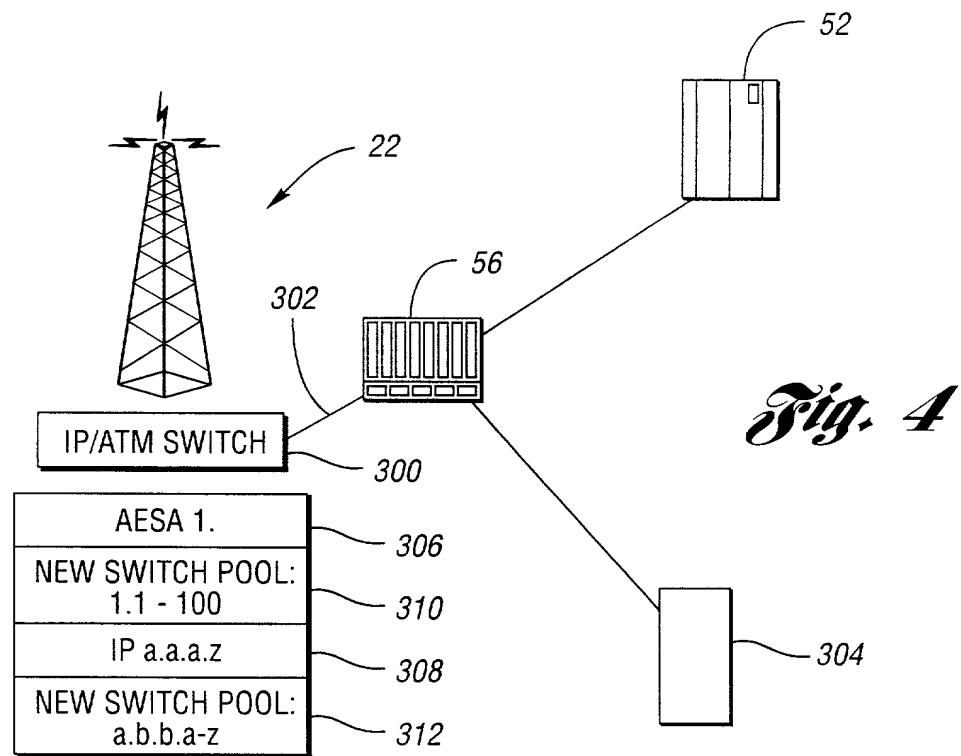


Fig. 4

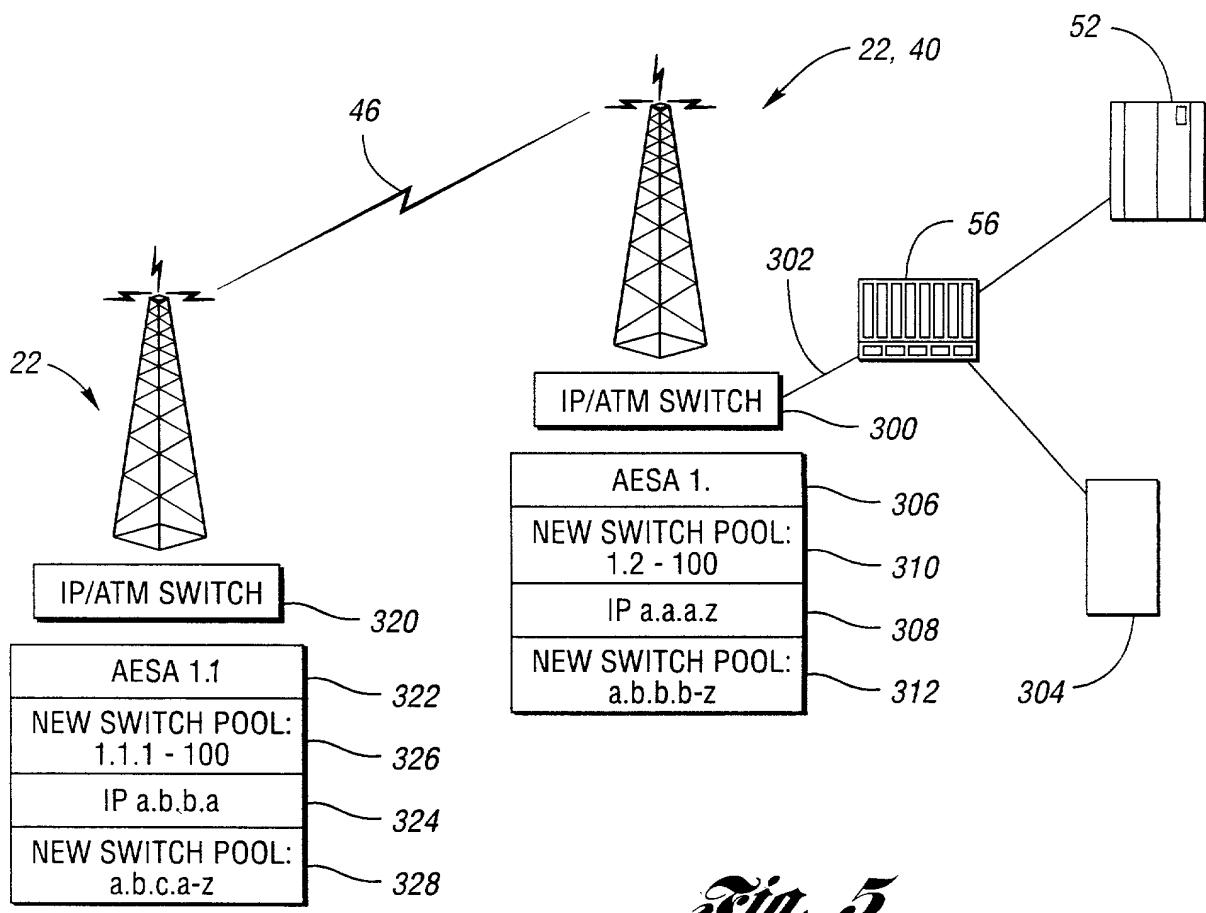


Fig. 5

Sij. 6

